Design of an Experimental Platform for Hybrid EEG-fMRI Neurofeedback Studies

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Authors:

Marsel Mano[1,2], Elise Bannier[3,2], Lorraine Perronnet[1,2], Anatole Lécuyer[1], Christian Barillot[2]

Institutions:

[1]Inria, Hybrid Team, Rennes, France, [2]Inria, VisAGeS Project-Team, Rennes, France, [3]Service de Radiologie, CHU Pontchaillou, Rennes, France

E-Poster

Introduction:

Neurofeedback (NF) can be defined as the self-regulated change of a particular brain activity that is reflected in the change of a neural signal or a combination of neural signals such as EEG, fMRI, MEG, etc. There exist a variety of unimodal (i.e. EEG or fMRI) NF researches [1-2], but very few with multimodal NF applications [3]. This is primarily because of the associated technical burdens [4-6].
The purpose of this abstract is to give a technical description of the hybrid EEG-fMRI system that we have developed for our NF experiments as part of the project Hemisfer[1], including the hardware/software components and their roles.

Methods:

Our system is based on the integration and the synchronization of MR-compatible EEG and fMRI acquisitions.
The EEG signals are acquired with a 64 channel MR-compatible solution from Brain Products (BP)[2]. The system uses a synchronization module to achieve EEG-fMRI phase synchronization, necessary for the MR gradient artifact removal [7] and an ECG channel for ballistocardiogram artifact removal [8].These artifacts are filtered in real-time using the vendor's software (*RecView*). Next, the EEG data is send via TCP/IP to the *EEG object* in Matlab. This object can pre-process, filter, extract features, train NF models and estimate EEG-NF in real-time. The results are sent to *Joint NF*.
The MR imaging is performed on a 3T Verio Siemens scanner (VB17) with a 12-ch head coil. High resolution structural 3D T1 is acquired, followed by task-related EPI acquisitions (TR/TE=2000/23ms, 2x2x4mm3 voxel size, 32 slices). The fMRI data is sent to the acquisition computer using a client/server buffer solution from FieldTrip[3]. The fMRI data is received and processed in real-time by the *fMRI object* in Matlab/SPM8. Besides acquisition, this object can pre-process volumes (i.e. realignment, slice-time correction, smoothing), extract ROI(s) and features, train NF models, and estimate fMRI-NF. The NF results are sent to the *Joint NF*.
The *Joint NF* does the fusion (i.e. averaging, normalizing, modeling, etc.) of the EEG and fMRI NFs, and then sends the results to *Visualize*. *Visualize* controls the display that communicates with the subject. It has a collection of visual objects (Matlab/Psychtoolbox) for explaining the NF tasks (i.e. texts) and for animating the NF representation (i.e. 2D/3D objects). Tasks/NF are transmitted using the NordicNeurolab[4] hardware.

Finally, the *NF Control object* contains the experiment protocol (types of tasks, duration, repetition, etc.). It starts/stops the experiment, controls all the other objects' behavior throughout the experiments, and stores the data.

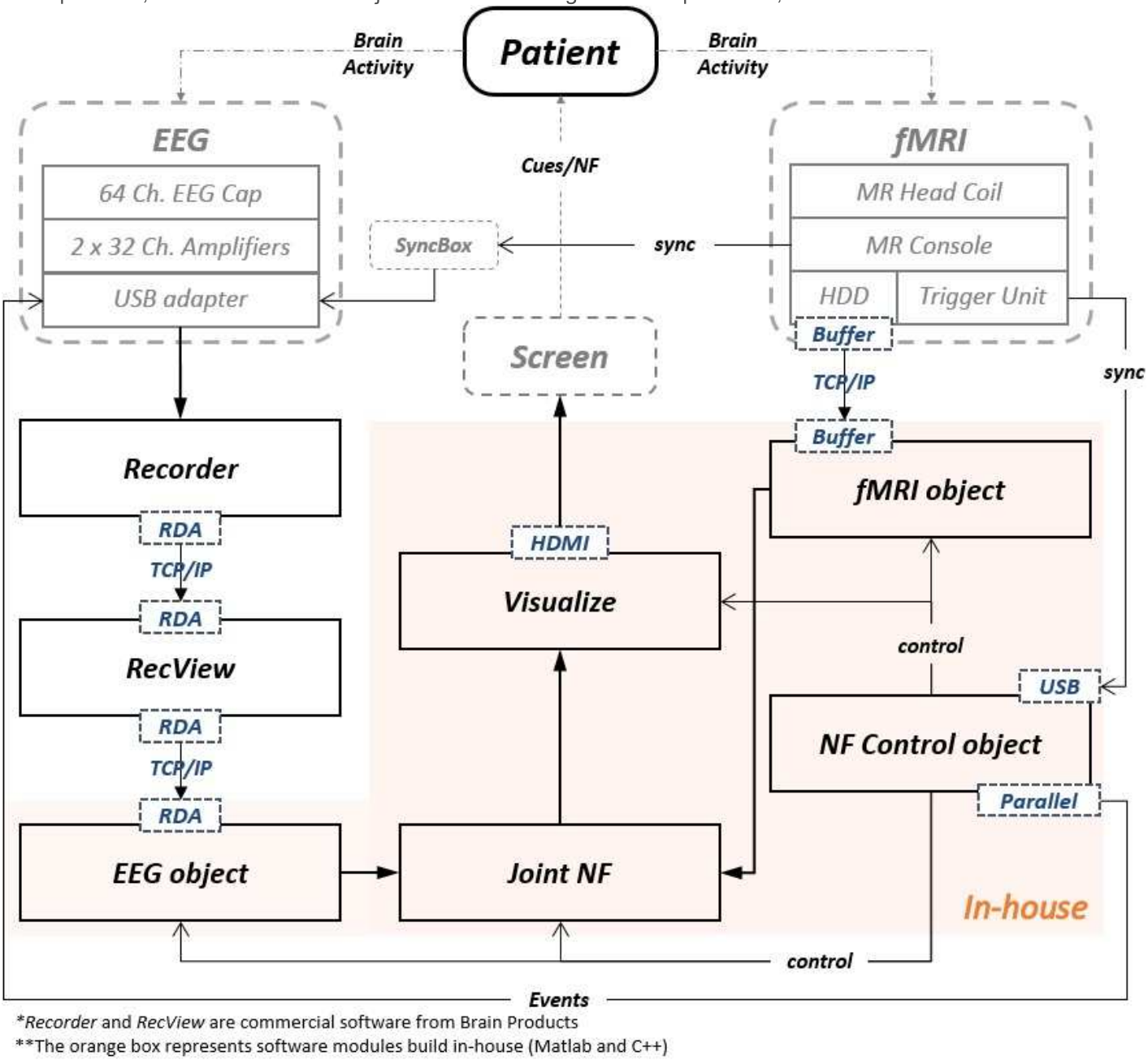

Figure 1. Diagram of the developed hybrid EEG-fMRI neurofeedback system

Results:

Our platform tests showed very good real-time performance with various pre-processing, filtering, and NF estimation and visualization methods. The entire fMRI process from acquisition to NF takes always less than 200ms, well below the TR of regular EPI sequences (2s). The same process for EEG, with NF update cycles varying 2-5Hz, is done in virtually real time (~50Hz).
Various NF tasks scenarios for regulating the measured brain activity were tested with subjects. In particular, the platform was used for a NF study on 10 subjects with over 50 sessions using three NF protocols based on motor imagery related brain activity: a) fMRI-NF, b) EEG-NF and c) EEG&fMRI-NF; and two online brain activity regulating protocols without NF. The task used in the experiments is shown in Fig.2.

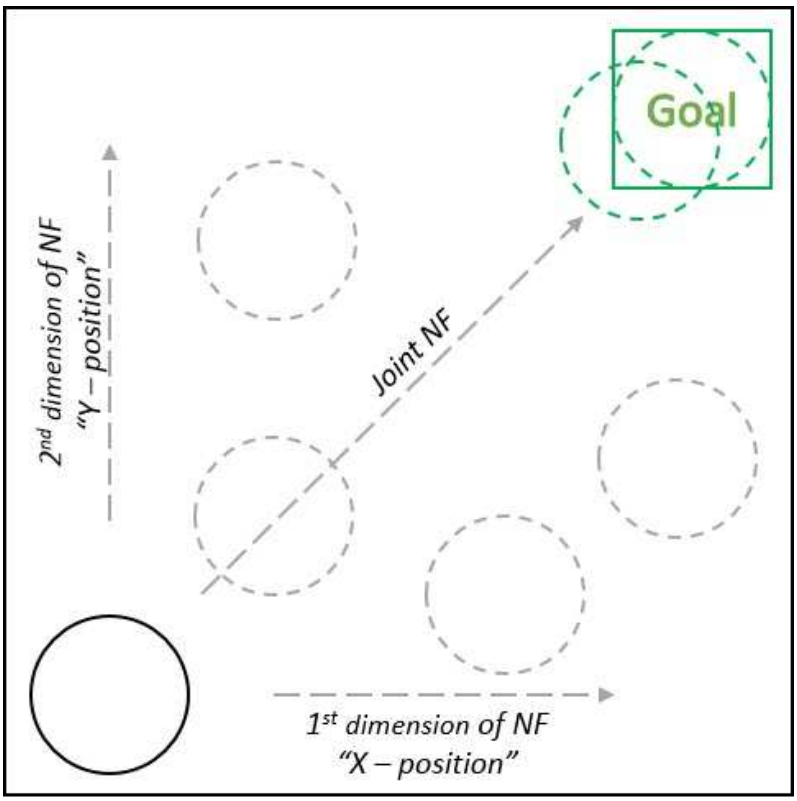

Figure 2. The NF task is to put the white circle into the green box (goal). The system uses the brain activity (EEG & fMRI) to estimate the NF and then translates it into 2D motion of the circle toward the goal.

Conclusions:

The system presented here offers a reliable platform for the hybrid EEG-fMRI NF experiments in our project. Its modular architecture is easily adaptable to different experimental environments, and offers high efficiency for optimal real-time NF applications.

[1]http://www.hemisfer.cominlabs.ueb.eu/
[2]http://www.brainproducts.com/
[3]http://www.fieldtriptoolbox.org/
[4]http://www.nordicneurolab.com

Imaging Methods:

Anatomical MRI
BOLD fMRI
EEG

Modeling and Analysis Methods:

Methods Development [1]
Multivariate modeling [2]

Poster Session:

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Keywords:

Electroencephaology (EEG)
FUNCTIONAL MRI
Other - Neurofeedback, real-time EEG, real-time fMRI, system desing

[1|2]Indicates the priority used for review

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Not applicable

Please indicate which methods were used in your research:

Functional MRI
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For human MRI, what field strength scanner do you use?

3.0T

Which processing packages did you use for your study?

SPM
Other, Please list - Brain Vision, FieldTrip, Psychtoolbox

Provide references in author date format

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